BOREAL INSTITUTE
LIBRARY
FEB 8 1972

gas arctic

SYSTEMS

Gas Pipeline RESEARCH in the Arctic Environment

Pam: 621.644: (*49) GAS c.1

POLAR
PAM
4179
POLARPAM

gas arctic systems study group

- The Alberta Gas Trunk Line Company Limited
  505 Second Street S.W.
  Calgary 2, Alberta

- Canadian National Railway Company
  935 Lagauchetiere Street W.
  Montreal 101, Quebec

- The Columbia Gas System Inc.
  20 Montchanin Road
  Wilmington, Delaware 19807

- Northern Natural Gas Company
  2223 Dodge Street
  Omaha, Nebraska 68102

- Texas Eastern Transmission Corporation
  Southern National Bank Building
  Houston, Texas 77001

As of September 3rd, 1971
Pacific Lighting Gas Development Company
720 West 8th Street
Los Angeles, California 90017

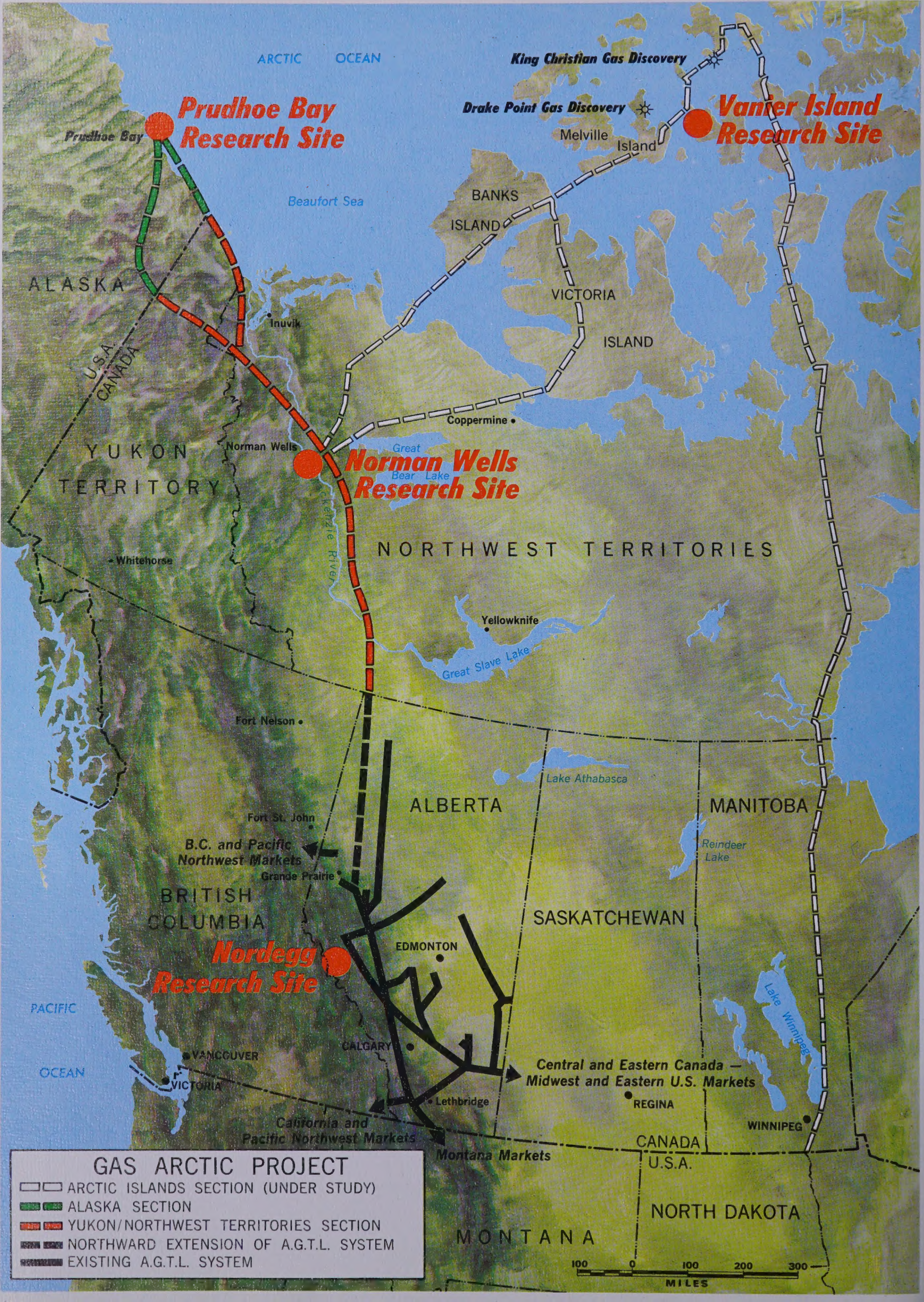
CONTENTS

Introduction 3
Prudhoe Bay Test Facility 5
Norman Wells Test Facility 10
Nordegg Test Facility 14
Channel Study 16
Terms and Meanings 17

c6454

Rec'd: FEB 8 1972
Order No.: Phone call Feb. 4/72
Price:
Acc. No.: Alta Gas Trunk Line Co.

Frost patterns — Canadian Arctic


ARCTIC OCEAN
King Christian Gas Discovery
Prudhoe Bay Research Site
Prudhoe Bay
Drake Point Gas Discovery
Vanier Island Research Site
Melville Island
Beaufort Sea
BANKS ISLAND
ALASKA
VICTORIA ISLAND
Inuvik
U.S.A.
CANADA
Coppermine
YUKON TERRITORY
Norman Wells
Norman Wells Research Site
Great Bear Lake
Mackenzie River
NORTHWEST TERRITORIES
Whitehorse
Yellowknife
Great Slave Lake
Fort Nelson
Lake Athabasca
ALBERTA
MANITOBA
Fort St. John
B.C. and Pacific Northwest Markets
Grande Prairie
Reindeer Lake
BRITISH COLUMBIA
SASKATCHEWAN
EDMONTON
Nordegg Research Site
Lake Winnipeg
PACIFIC OCEAN
CALGARY
VANCOUVER
VICTORIA
Central and Eastern Canada — Midwest and Eastern U.S. Markets
Lethbridge
REGINA
California and Pacific Northwest Markets
WINNIPEG
CANADA
U.S.A.
Montana Markets
GAS ARCTIC PROJECT
ARCTIC ISLANDS SECTION (UNDER STUDY)
ALASKA SECTION
YUKON/NORTHWEST TERRITORIES SECTION
NORTHWARD EXTENSION OF A.G.T.L. SYSTEM
EXISTING A.G.T.L. SYSTEM
NORTH DAKOTA
MONTANA
100 0 100 200 300
MILES

Introduction

The story is an old and familiar one in the natural gas industry: the discovery of large reserves at a great distance from centres of demand. It's the setting which is new and different.

No one has ever built a gas pipeline through the combination of harsh climate, rugged terrain and delicate ecological balances which characterizes the space between recent gas discoveries in Alaska and the Canadian Arctic, and the factories of Hamilton, Ontario, or the homes of Columbus, Ohio.

The Gas Arctic Systems Study Group is confident that it can be done, economically and safely. The companies belonging to the group are sponsoring four Arctic research operations designed to discover how the line can best be built. And they have committed millions of dollars to this task.

Basically, the reasons for this research program reflect the reasons why the Gas Arctic Systems Study Group was formed in the first place.

Natural gas in volumes indicated by recent Arctic discoveries is in demand in other parts of the continent. The remote location of Prudhoe Bay, Alaska, or King Christian Island, Northwest Territories, no longer weighs heavily against utilization of Arctic gas. The combination of intensifying need, new technology and improved economic feasibility has radically altered the status of many reserves which until recently were considered beyond economic reach of market.

The Arctic discoveries thus represent new supplies for several of the members of Gas Arctic. For others they spell opportunity in the form of increased need for gas transportation service.

The Gas Arctic Systems Study Group believes that Arctic gas is within economic reach of markets via a 48-inch pipeline from Prudhoe Bay to a connection with the Alberta Gas Trunk Line Company's system near Grande Prairie, Alberta. The group has already embarked on a multi-million-dollar engineering and research program to assess all aspects of the construction of such a line.

The pipeline proposal raises many questions about the possible effects of pipelines on the environment, and the possible effects of environment on pipe. The research is directed to finding the answers, so that from them the appropriate techniques and methods can be developed.

The questions are represented by such terms as tundra, muskeg and permafrost.* The search for answers involves the use of devices such as transducers, thermocouples and conductivity probes, plus a sophisticated mathematical solution technique.

The Gas Arctic Systems Study Group is studying these questions through simultaneous investigations on many fronts. There are studies of economics, engineering and the ecology all along the proposed pipeline route.

This brochure describes part of this program in terms of the facilities and instrumentation which have been installed at Prudhoe Bay, Alaska; Norman Wells, Northwest Territories; and Nordegg, Alberta; and the work going forward on Vanier Island, N.W.T.

Facilities at the first three test sites are to serve several purposes. Firstly, they will facilitate assessment of immediate gross effects on the surface as observed visually. Secondly, they are designed to make possible the quantitative measurement of heat transfer and other natural properties in order to provide basic functions for a mathematical analytical technique that will be used for long range prediction of Arctic soil behaviour. Thirdly, they will be used to help develop measures for effective restoration of the disturbed soil cover.

Development of an accurate mathematical solution technique will enable engineers to make valid predictions of future performance of design concepts and construction methods, and thus will enable the choosing or developing of those designs that are most effective in permafrost and economical to use.

The mathematical solution technique requires a sophisticated computer code that can predict, over a long period of time, soil properties at a multitude of points at various depths across a pipeline right-of-way. This work is being done by a large group of technical experts highly qualified in the fields of soils mechanics, instrumentation, heat transfer, thermal soils behaviour, and mathematical computer techniques.

Instrumentation of the test sites is largely determined by the needs of the prediction model.

* Readers not familiar with these terms may wish, before reading on, to consult the section on terms and meanings on page 17.

Winter pipeline construction

Why three test sites? The pipeline conditions encountered along the 1,550 miles of the proposed route are varied to the extent that no one location would be adequate in itself for the purpose of seeking answers to all the questions.

The companies belonging to the Gas Arctic Group feel not only that there is urgent need for answers to the problems of gas pipelining across the Arctic mainland, but that it is timely to begin research into the problems of pipelining from island to island in the Arctic archipelago, where substantial reserves of gas have already been discovered.

To this end a channel study, centred in the waters around Bathurst Island, has been undertaken. This fourth major pipeline research operation is also described in the following pages.

One type of terrain to be crossed by Gas Arctic

Prudhoe Bay

Basic facility — a 2,000 foot rectangular operating loop of 48-inch pipe.

Test gas — air.

Operating temperature—range 0 to 65 degrees Fahrenheit.

Timetable — at least one year of operation, beginning July 15, 1971, with initial evaluation to be completed by October 1, 1972.

Cost — $2,000,000 including construction, one year of operation, analysis and associated soils testing programs.

Design — Battelle Memorial Institute, Columbus, Ohio, and Pipeline Technologists Inc., Houston, Texas.

Construction — Wagley Incorporated, Anchorage.

Operation—Pipeline Technologists Inc., under general supervision by Battelle Memorial Institute.

Evaluation — Battelle Memorial Institute.

The main element of Gas Arctic's test installation at Prudhoe Bay is a 2,000-foot loop of line pipe, in which air can be circulated at low pressure and at temperatures ranging from 0 to 65 degrees Fahrenheit.

The reason for the temperature range selected is to demonstrate that a gas pipeline operating at permafrost temperature will not initiate thermal erosion by melting the surrounding soil. There is a bonus for the gas pipeliner in the use of such operating temperatures, since cool gas can be transported much more efficiently through the line. As a matter of fact the design of the proposed Gas Arctic line includes provision for re-refrigerating the gas at each compressor station.

The installation includes the means of heating the test gas to 65 degrees, to see what the effect of operation in that temperature range would be. This will not be done, however, until after at least a full year of operation at cool temperatures.

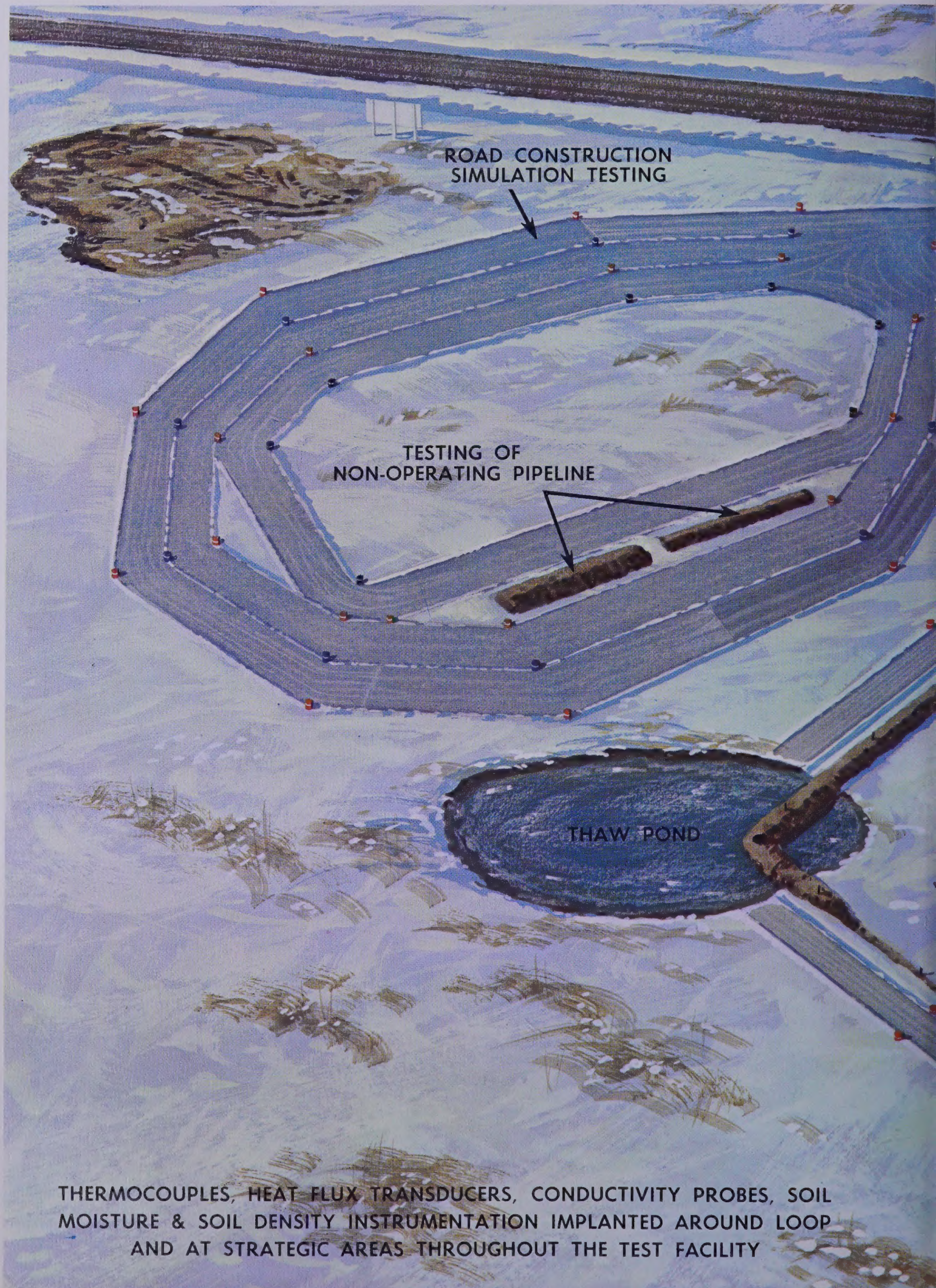
Because natural gas is not available at the test sites, air is being used as the test medium. The properties of air, which is really a mixture of gases, are well known. Data obtained from operations with air can be readily translated into terms of the behavior, under the same conditions, of natural gas.

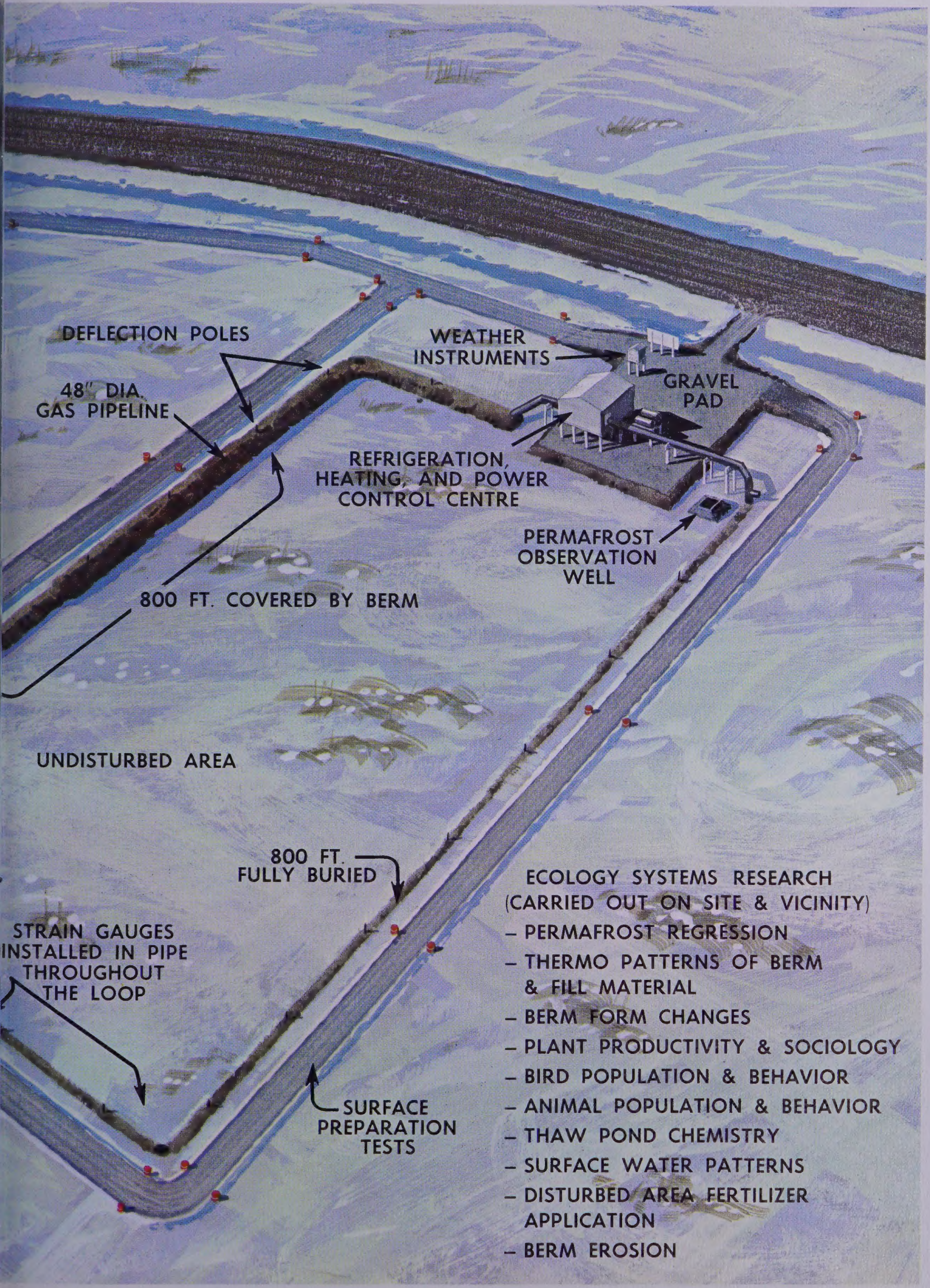
One 800-foot side of the pipeline loop is buried in the conventional manner. The opposite side is half-buried in a shallow trench and covered with soil forming a berm. One 200-foot end section contains the equipment and controls used to operate the loop, the other is used to make the transition from burial to berm. The corner on the berm side is in a thaw pond. Various types and thicknesses of backfill have been used to cover the pipe at various points, both where it is buried and where it is covered by a berm.

In order to determine what effects there may be from the operation of a pipeline in such a permafrost area, the test program will first of all measure heat flows between the gas in the pipe and the surrounding ground,

Two stages of construction at Prudhoe Bay

Prudhoe Bay Test Facility


ROAD CONSTRUCTION SIMULATION TESTING
TESTING OF NON-OPERATING PIPELINE
THAW POND
THERMOCOUPLES, HEAT FLUX TRANSDUCERS, CONDUCTIVITY PROBES, SOIL MOISTURE & SOIL DENSITY INSTRUMENTATION IMPLANTED AROUND LOOP AND AT STRATEGIC AREAS THROUGHOUT THE TEST FACILITY


DEFLECTION POLES
48" DIA. GAS PIPELINE
WEATHER INSTRUMENTS
GRAVEL PAD
REFRIGERATION, HEATING, AND POWER CONTROL CENTRE
PERMAFROST OBSERVATION WELL
800 FT. COVERED BY BERM
UNDISTURBED AREA
800 FT. FULLY BURIED
STRAIN GAUGES INSTALLED IN PIPE THROUGHOUT THE LOOP
SURFACE PREPARATION TESTS
ECOLOGY SYSTEMS RESEARCH (CARRIED OUT ON SITE & VICINITY)
– PERMAFROST REGRESSION
– THERMO PATTERNS OF BERM & FILL MATERIAL
– BERM FORM CHANGES
– PLANT PRODUCTIVITY & SOCIOLOGY
– BIRD POPULATION & BEHAVIOR
– ANIMAL POPULATION & BEHAVIOR
– THAW POND CHEMISTRY
– SURFACE WATER PATTERNS
– DISTURBED AREA FERTILIZER APPLICATION
– BERM EROSION

In each of several places on the loop, heat flux transducers and thermocouples are attached to the outer wall of the pipe, at uniform intervals around its circumference. (Transducers are composite plates sensitive to the passage of heat in either direction.) A continuous record will be kept of heat flow through the wall of the pipe. Since the temperature of the test gas is also being recorded, the other readings necessary to provide a complete picture are those of atmospheric temperature and the heat transfer characteristics of the soils.

Air temperature readings are comparatively easy to obtain, using the equipment which is standard with weather men throughout the Arctic. Soil temperatures present a different problem, and in order to obtain readings it has been necessary to place thermocouples in the soil of the test site.

Most of them are in five main groups, three along the buried section of the pipe, the other two along the bermed section. Similar patterns and spacing are used in positioning the thermocouples, some of which are as much as 45 feet out from the centre line of the pipe, some as much as 18 feet below the surface of the ground. The concentration of thermocouples is greatest near the pipe, where the greatest temperature differences are likely to occur.

There is a pattern also to the frequency of reading the instruments. First of all, frequency depends on the location of individual instruments. Those in critical locations are read most often. But frequency depends also on the need for time intervals to be related mathematically so that all data will fit harmoniously into the computer program being used in data analysis.

The instruments in each of the five main groups are set in a vertical plane at right angles to the axis of the pipe. There are, however, other instruments placed singly and in small groups at apparently random locations on the site. Each of these has been placed for a special purpose: one under the thaw pond, several under the traffic test area which will be described presently, some under two closed modules of pipe containing static air, a few under the gravel pad on which the test site's buildings rest.

These, in general, are for the purpose of seeing whether the presence of buildings, or the passage of traffic, or the disturbance of the surface has any effect on temperatures below the surface.

But the geochemistry and soil mechanics of pipelining in the Arctic are much too complex to be studied in terms of temperature alone. The water content of the soil, the mechanics of freezing and thawing, water migration and the solubility of soil chemicals in water are only a few of the other factors which must be taken into account.

To obtain data on these, the researchers carrying out the test program are using specially developed probes to measure soil moisture and density, while other instruments are used to take readings of water pore pressure, thaw consolidation and various physical and chemical properties of the soil, water and soil-water mixtures.

There are also vegetation and revegetation tests.

The reference made earlier to a **traffic test area represents another aspect of the test program, designed to assess the effects of construction activity.** Near the pipeline loop are three concentric rings of vehicle tracks, made by repeated passes over a series of plots where different surface preparation techniques were used in an attempt to discover which affords the best protection for the tundra and/or permafrost.

Finally, the instrumentation at Prudhoe includes strain gauges to measure stresses on the pipe produced by ground pressure or movement, and deflection poles set along the pipe to detect any lateral or vertical displacement.

The Prudhoe site represents continuous permafrost with a high ice content at a temperature well below freezing. For research purposes it is almost perfectly complemented by the Norman Wells site.

Prudhoe Bay facility during construction.

Norman Wells

Basic facility — four closed modules, each consisting of 120 feet of 48-inch pipe.

Test gas — air.

Operating temperatures — 10 to 20 and 50 to 70 degrees Fahrenheit.

Timetable — at least one year of operation, beginning August 1, 1971, and evaluation simultaneous with that of Prudhoe data.

Cost — $750,000 including construction, one year of operation and associated soils testing program.

Design — The Alberta Gas Trunk Line Company's Gas Arctic Project Group, with approval by Battelle Memorial Institute.

Construction — Norman Wells Transportation.

Operation — The Gas Arctic Project Group, with engineering support from Pipeline Engineering and Management Services of Canada.

Evaluation — Battelle Memorial Institute.

The Norman Wells test site represents intermittent permafrost with a much lower ice content than that at Prudhoe, at a temperature very close to the freezing point of water. For this reason a much different test installation was designed.

In each of the four pipe modules, circulation of the test gas is achieved by the use of a 30-inch tube of sheet-metal ducting placed inside the 48-inch pipe. The gas is propelled from one end of the module to the other through this duct, and returns through the space between the duct and the pipe.

In two of the modules, a gas temperature of about 10 to 20 degrees Fahrenheit is maintained. In the other two the temperature is between 50 and 70 degrees. One warm-gas module is buried in a conventional pipeline ditch, the other lies in a shallow trench with berm over. The two cool-gas modules have been treated similarly: one buried, one bermed.

In many ways the kind of testing being done at Norman Wells is the same as at Prudhoe.

As at Prudhoe, there are two closed pipe modules (one buried, one bermed), in addition to the main operating test installation. In these, as at Prudhoe, there is no circulation of the test gas, the purpose being to see what events or changes may result strictly from the

All photos of this and preceding page are of construction at Norman Wells

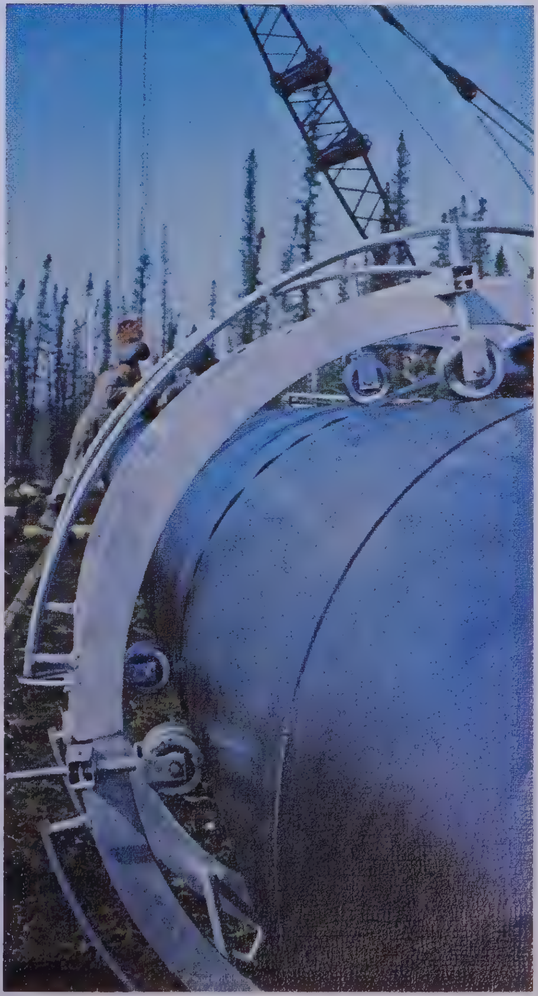
presence of pipe in the ground. As at Prudhoe, the test data will be converted into terms of the behaviour of natural gas. As at Prudhoe, heat flow through the walls of the line pipe is being measured by transducers placed around each module.

Here, too, the site has been extensively cored. There are measurements being made of soil characteristics, and weather observations are being recorded. There are thermocouples to indicate soil temperature in special places such as in the gravel pad under the buildings and even under the place where a brush pile was burned.

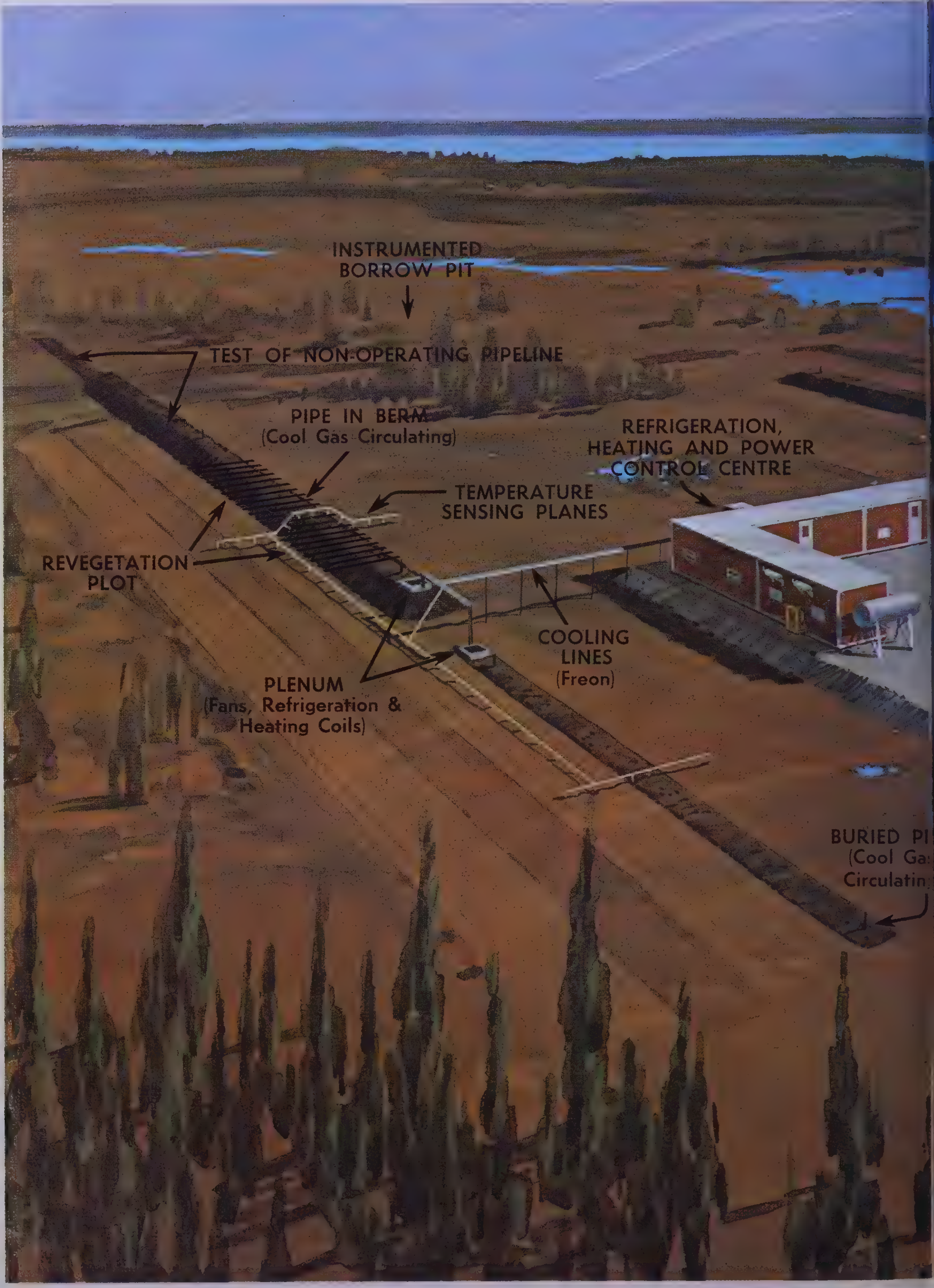
The main instrumentation in the vertical planes intersecting the four modules will consist of resistance temperature detectors.

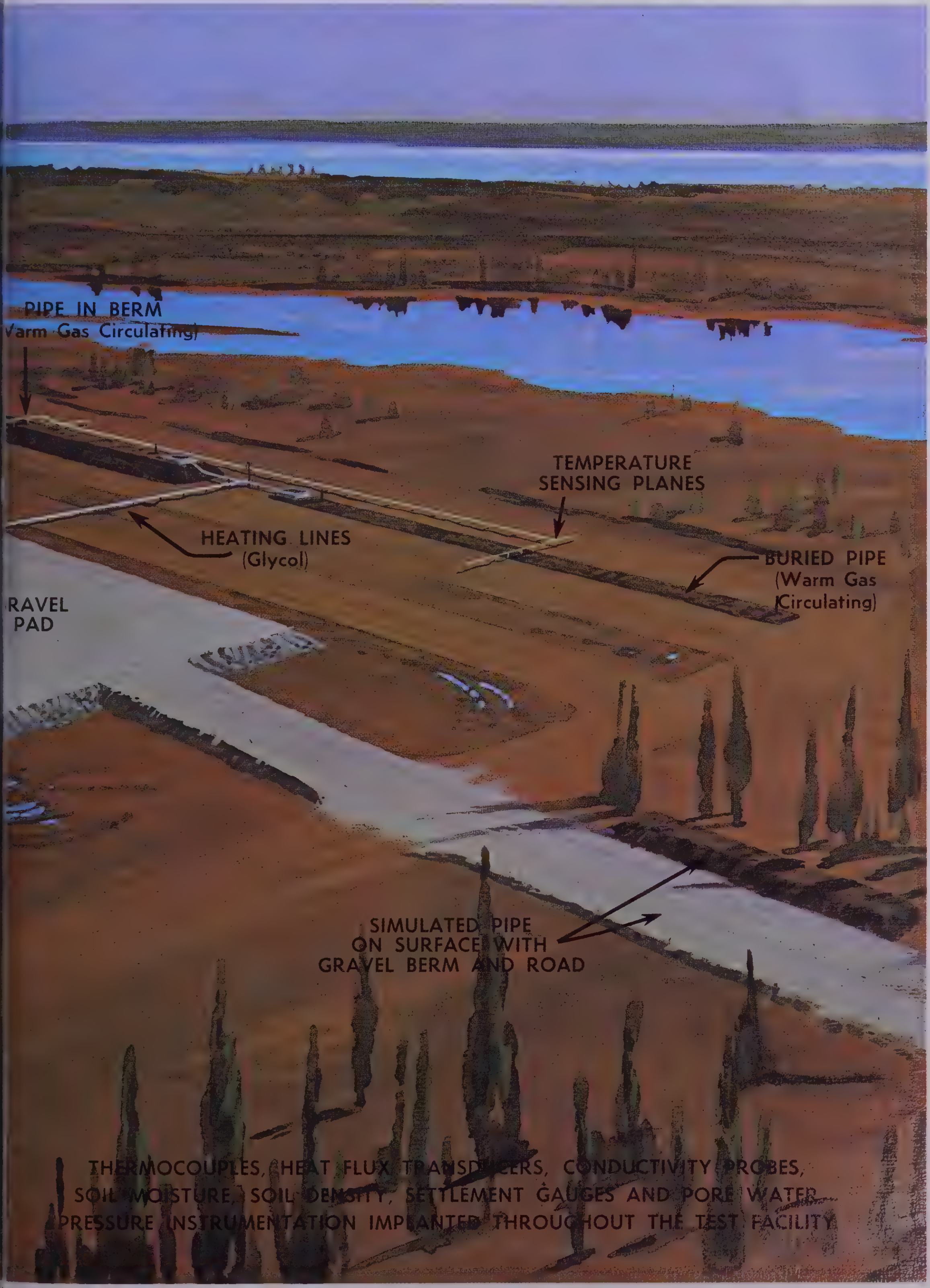
Instruments are positioned across the entire 100-foot right-of-way which has been staked out paralleling each module, again with the greatest concentration close to the pipe. Some instruments will also be located in a line along the pipe.

Part of the soils program at Norman Wells involves the suitability of the soil for rapid revegetation by introduced plant species, and seeding has already been carried out. This is one of the important similarities to the test operation at Nordegg.



Norman Wells Test Facility


INSTRUMENTED BORROW PIT
TEST OF NON-OPERATING PIPELINE
PIPE IN BERM (Cool Gas Circulating)
REFRIGERATION, HEATING AND POWER CONTROL CENTRE
TEMPERATURE SENSING PLANES
REVEGETATION PLOT
COOLING LINES (Freon)
PLENUM (Fans, Refrigeration & Heating Coils)
BURIED PI
(Cool Ga
Circulatin


PIPE IN BERM
(Warm Gas Circulating)
TEMPERATURE SENSING PLANES
HEATING LINES (Glycol)
BURIED PIPE (Warm Gas Circulating)
RAVEL PAD
SIMULATED PIPE ON SURFACE WITH GRAVEL BERM AND ROAD

THERMOCOUPLES, HEAT FLUX TRANSDUCERS, CONDUCTIVITY PROBES, SOIL MOISTURE, SOIL DENSITY, SETTLEMENT GAUGES AND PORE WATER PRESSURE INSTRUMENTATION IMPLANTED THROUGHOUT THE TEST FACILITY

Nordegg

Basic facility — a one-mile operating section of 42-inch line in a loop of the Alberta Gas Trunk system.

Test gas — flowing market gas.

Operating temperatures — seasonal norms for the system, typically 30 degrees F. in spring, 50 to 55 degrees F. in summer.

Timetable — data gathering began in the spring of 1971 and will continue indefinitely.

Design — The Alberta Gas Trunk Line Company Limited.

Construction — carried out as part of 1970 looping program.

Operation — The Alberta Gas Trunk Line Company Limited.

Evaluation — Battelle Memorial Institute.

The right-of-way and the instrument building on the Nordegg test section

Seeding the berm which covers the Nordegg test section will offer a unique opportunity to compare the growth of two new vegetation covers planted five years apart.

The test section parallels, at a distance of 30 feet, a 30-inch buried line laid in 1965. The new vegetation over the 30-inch line was already well established before the 42-inch was installed during the fall of 1970.

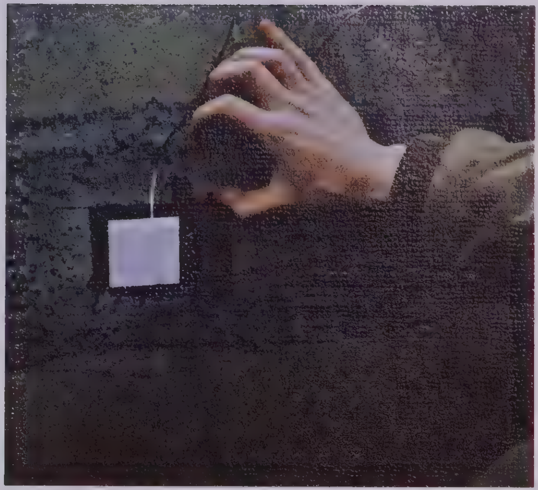
The chief advantage of the Nordegg test is that observations can be made here of gas temperature and heat movement in an operating pipeline.

There are thermocouples and transducers implanted around both the 42-inch and 30-inch lines. Thermocouples have been placed in the soil in patterns similar to those employed at the other sites, out to 50 feet from the 42-inch line, out to 30 feet from the smaller pipe. Again, the concentration of instruments is greatest closer to the pipe.

One minor difference from the other two test projects is created by the fact that temperature cannot be measured by inserting instruments into an operating line unless provision was made during construction. This problem has been met by using temperature and pressure readings taken at a compressor station down stream from the test section and a pressure reading at the instrumentation point, to calculate the temperature of the flowing gas at the research area.

There is one other important fact about the Nordegg test. That section of the line runs through muskeg and wet clay. It is thus serving as a **test of the berm technique, taking advantage of the natural buoyancy of a gas pipeline to achieve the effect of having the line "float" in the wet soil, so that stresses on the pipe are reduced to a minimum and the cost of weighting, which can run to $140,000 per mile in Alberta, is eliminated.**

Gas Arctic is confident that this technique will prove useful on those stretches of the proposed line farther north where muskeg or other wet ground poses problems.



A heat flux transducer in place

Miles of fine instrument wire

Muskeg travel is a special problem

The Arctic Islands

Channel ice

Channel Study

Timetable — completion in 1971.

Operation — Pipeline Engineering and Management Services of Canada.

The fourth item in Gas Arctic's catalogue of research projects is virtually unique, since it covers aspects of pipeline research ranging from route location to construction techniques.

This is the Arctic Islands channel study being carried out from a base camp on Vanier Island, a bleak and lonely map-dot which is still south of the centre of Canada's Arctic archipelago, yet almost in the same latitude as the famed United States defence base at Thule, Greenland.

Here a team of scientists and pipeline specialists is working on the ice between the islands, **gathering information which Gas Arctic must have before deciding where and how a pipeline can be built to carry the gas already known to exist beneath the Arctic Islands and the channels which separate them.**

Their immediate assignment is to gather data in the waters north of and adjacent to Bathurst Island, including **information on ice types, ice thickness and ice movement.** The group is also **measuring depths and currents, charting the profile of the ocean floor, and examining the nature and thickness of the bottom sediments.**

The program consists almost entirely of new research, since very little information is available for the Arctic Islands north of the main channel of the Northwest Passage. There has been little navigation there, so few measurements of water depth, currents and ice have ever been recorded.

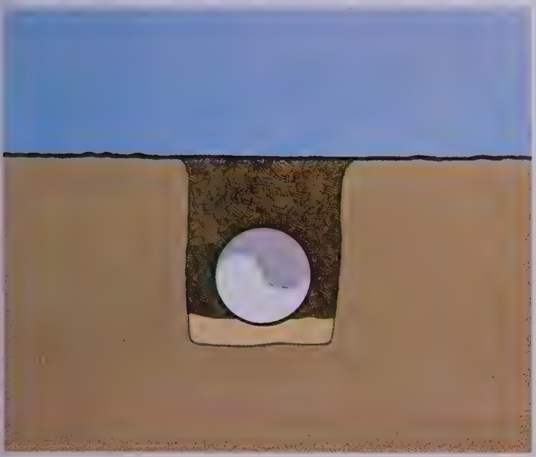
The program is being carried out in close liaison with Canadian government and other agencies which have developed such data and techniques as are available, in order to avoid duplication of effort. Gas Arctic is working in harmony with the Polar Continental Shelf group, a research instrument of the Canadian federal government.

The program is the first group of specific studies to result from the initial feasibility study of the Arctic Islands begun by Gas Arctic in March, 1971, and carried out by PEMCAN Services (Pipeline Engineering and Management Services of Canada).

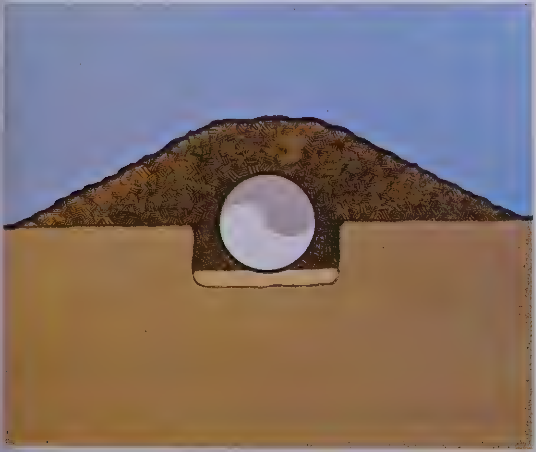
Terms and Meanings

The subject of this brochure makes it necessary to use frequently a number of terms which have only recently entered general usage — terms such as tundra, muskeg and permafrost.

These terms are still widely misunderstood and often misused. Unfortunately, some of the terms, while clearly understood by the scientist, are misleading to the layman because he naturally interprets them by the ordinary meanings of the words used.



Cross section illustrating conventional method of burying pipe entirely below grade.



Pipe laid in shallow ditch, half below grade, half above, then covered with earth berm.

One example is the "active layer of permafrost", which contains an apparent contradiction of terms, as will be seen presently.

Permafrost is not really a thing or substance, but a condition. Wherever the material below the surface of the ground is permanently frozen, permafrost exists. More correctly, there is permafrost wherever the water in that material is permanently frozen. This is true whether the material be moisture-laden soil, rock or muskeg. (In practice, scientists refer to permafrost even where there is no moisture — if the subsurface material is rock containing no pores, for example, or porous rock containing no water.) The process which creates permafrost is heat loss to the atmosphere. If the rate of heat loss is sufficient to keep the temperature of the soil or rock below 32 degrees Fahrenheit (the freezing temperature of water), then the condition is that of permafrost.

In much of Northern Canada the permafrost is continuous over many miles. Along the route of the proposed Gas Arctic pipeline, this area of continuous permafrost extends to a point just south of Arctic Red River, N.W.T.

South of a line running through that point is an area of "discontinuous" permafrost extending, in terms of the pipeline route, to a point slightly south of Fort Vermilion, Alberta.

The test site at Prudhoe Bay is therefore in continuous permafrost, that at Norman Wells in the discontinuous permafrost area, and the one near Nordegg, Alberta, in an area free of permafrost.

Discontinuous permafrost is sometimes described as being intermittent, which some feel is more accurately descriptive, since the permafrost condition occurs in areas ranging in size from a few square yards to many acres or even square miles, often widely separated.

In general, the farther North permafrost occurs the thicker it is, ranging from a few inches in some places to measured depths

approaching 2,000 feet at several locations on the Arctic Islands.

Thickness, however, is not always a source of difficulties. On the Arctic Islands, for example, or in much of the pipeline route through the Brooks Range in Alaska, it is rock which is permanently frozen. For the pipeliner, frozen rock presents no problems substantially different from the difficulties of working in unfrozen rock.

It is where the permafrost occurs in muskeg or moisture-laden soil that the more complex problems are encountered.

Whether continuous or intermittent, permafrost occurrence has another characteristic which creates problems for the pipeliner. The permanent freezing does not extend to the surface, although it may come within a few inches of it.

The vegetation and other material overlying the permafrost proper is frozen only in winter. Each summer it thaws, and so this surface material is referred to as the "active" layer of permafrost. It is active, but it is not, strictly speaking, permafrost.

Because it is active, however, it creates problems.

Over the centuries, an equilibrium has developed within the active layer of soil. When ice within it melts, the water formed usually remains where it is in ponds and pools, since over much of the Arctic there is very poor drainage. The amount of melting is dictated by the length of the season with temperatures above freezing. If this season was to be extended, the melting would go deeper, more water would be formed and the equilibrium would be upset. It is upset just as easily if deeper-than-usual melting occurs for any other reason.

Over large portions of the Arctic, the ground surface is covered by **tundra — a thin mat of lichens, mosses and other vegetation adapted to the Arctic climate.** This organic mat serves as insulation, limiting the transmission of solar heat through to the permafrost. If this insulating layer is removed, as by a bulldozer cutting a road, the equilibrium of the active layer of soil just beneath the tundra is upset by additional melting during the following summer.

Evaporation or runoff of the additional water can then occur, permanently altering the composition of the surface layer. Having lost some of its moisture, the soil slumps, creating gullies or new ponds. In succeeding summers, melting progresses deeper, in a process called thermal erosion.

Even if the thermal erosion is arrested in a comparatively short time, the existence of even a small gully represents a new condition in which the upper profile of the active layer of soil has been lowered. The conditions which made a certain thickness of soil active before the disturbance re-assert themselves, and so the upper surface of the permafrost is pushed downward. This is called permafrost regression.

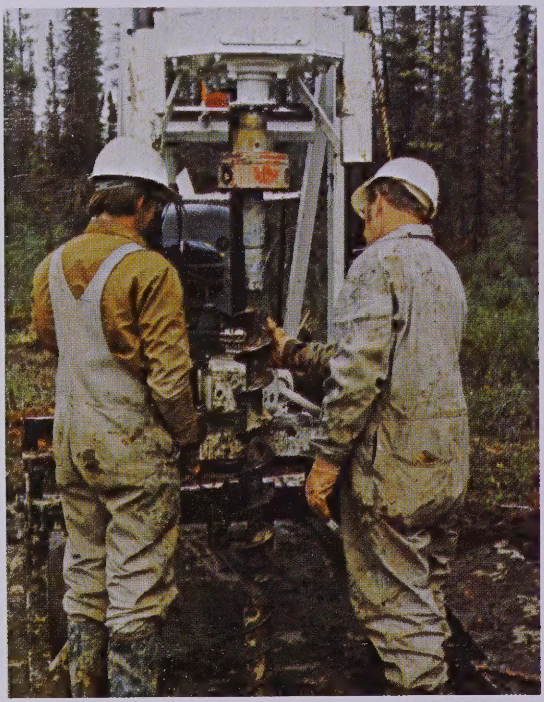
Permafrost in high-moisture-content soils that lose their stability and strength on melting, is referred to as detrimental permafrost. The regression of detrimental permafrost is a severe hazard.

In parts of the Arctic the surface is not covered by tundra and the exposed upper layer of soil is muskeg. This situation represents somewhat different problems, but the effects of disturbance can be just as pronounced.

Muskeg is a humus soil. That is, it is composed of decayed and decaying organic matter, with little or no mineral content. Scientists recognize 17 different basic types of muskeg, each with different characteristics ranging from those of a compost heap to those of a peat bog. Almost always, however, **muskeg contains so much moisture that when the water is not frozen the whole mixture behaves like a liquid rather than a solid, as is the case with quicksand.** As with other soils, disturbance of the muskeg might lead to water loss, slumping and a similar chain reaction.

The conditions described by these terms represent some examples of the difficulties encountered by pipeliners in the Arctic.

Soils Research



A portfolio of soil-coring photos

Date Due

JUL 20 '72			
OCT 25 '72			
MAR 1 '73			
JAN 29 '74			

Pam:621.644:(*40)
GAS
c.1

06454

AUTHOR Gas Arctic Systems Study Group

TITLE Gas pipeline research in the
Arctic environment

DATE LOANED	BORROWER'S NAME	DATE RETURNED
OCT 11	D.K. Becker	OCT 25 '72
FEB 15	James W Pasco	MAR 1 '73
JAN 22 '74	L. Clayton	JAN 29 '74

06454

BOREAL INSTITUTE
LIBRARY

PHOTOGRAPHY:
The Alberta Gas Trunk Line Company Limited, Calgary.
National Research Council of Canada, Ottawa.
Northern Natural Gas Company, Omaha.
John Patrick, Calgary.
Pemcan Services, Calgary.
Pipe Line Technologists Ltd., Anchorage.
R & M Engineering & Geological Consultants, Fairbanks.
J. C. Sproule & Associates Ltd., Calgary.

Lithographed in Canada
Western Printing & Lithographing Co. Ltd.
Calgary, Alberta

University of Alberta Library
0 1620 0335 2695